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AIRCRAFT AND EQUIPMENT FACTORS IN THE OCCURRENCE OF SUSPENSION LINE TWISTS WITH THE T-10 AND MC1-1B PARACHUTES

William P. Burke

ARI FIELD UNIT AT FORT BENNING, GEORGIA

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Subsequent work with the proportion of jumpers with twists from jumps made under different conditions of deployment. Using this method, it was shown that there was no effect of type of parachute on the occurrence of twists but there was a strong and significant effect of combat equipment which is associated with an increase in the proportion of twists. There was, in addition, a significant, but slightly smaller, effect of type of aircraft used for jumps, with more twists occurring during jumps from the C-141 than during jumps from the C-123.

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**AIRCRAFT AND EQUIPMENT FACTORS IN THE
OCCURRENCE OF SUSPENSION LINE TWISTS
WITH THE T-10 AND MC1-1B PARACHUTES**

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FOREWORD

The US Army Research Institute (ARI) Field Unit at Ft Benning, Georgia, is strategically located at one of the centers of airborne training for the United States military and has ready access to numerous individuals who are engaged in parachute jumping or related activities. This research was initiated in response to a request from BG John E. Rogers, Assistant Commandant of the US Army Infantry School to determine the causes of dangerous mid-air entanglements between jumpers.

One factor in the occurrence of entanglements is lack of canopy control by jumpers due to parachute suspension line twists. This report describes research into causes of suspension line twists during jumps in the Basic Airborne Course at Ft Benning. The data described here will be of particular interest to agencies involved in improving the design and utilization of individual combat equipment for airborne operations.



JOSEPH ZEIDNER
Technical Director

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This research was made possible by generous cooperation of the Director of the Airborne Department at Fort Benning, COL Joseph A. Villa. Special assistance to this project was provided by CPT Vernon Campbell, Chief of Jump Training Branch, and his cadre of Jumpmasters.

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AIRCRAFT AND EQUIPMENT FACTORS IN THE OCCURRENCE OF SUSPENSION LINE TWISTS
WITH THE T-10 AND MC1-1B PARACHUTES

BRIEF

OBJECTIVE:

To develop evidence of the effects of type of parachute, type of aircraft, and type of equipment carried on the occurrence of suspension line twists during jumps with the T-10 and the MC1-1B parachutes.

PROCEDURE:

This research was done with two classes of the Basic Airborne Course at Fort Benning, Georgia, during August 1979. The trainees of these classes were asked whether or not they had developed twists in their suspension lines during each of the five jumps of the Airborne training program. Each of the jumps of the course differed from the other in the conditions under which it was made. The jumps differed according to such factors as type of parachute employed, type of equipment carried, and amount of delay between jumpers. In addition, two different types of aircraft, the C-123 and the C-141, were used for most jumps.

The influence of each factor on the occurrence of twists was studied by using the Pearson Chi-square Test of Statistical Association to compare the proportion of jumpers with twists during each jump, with its associated conditions of deployment, to the proportion of jumpers with twists during other jumps made under different conditions of deployment.

FINDINGS:

The analyses indicated that there was no effect of type of parachute on the occurrence of twists but a strong effect of combat equipment. Combat equipment jumps resulted in large and significant increases, relative to non-equipment jumps, in jumpers who reported one or more twists. There were, in addition, significant increases in the proportion of jumpers reporting four or more and seven or more twists after combat equipment jumps as compared to non-equipment jumps.

There was also a significant, but slightly smaller effect attributable to the type of aircraft used for jumps, with more twists occurring during jumps from the C-141 than during jumps from the C-123. This was also true for the proportion of jumpers reporting four or more twists, but there was no difference between aircraft for the seven-or-more-twist category.

This research was a pilot investigation into the relationship between some possible causative factors and the occurrence of suspension line twists during parachute jumps. The individual factors studied in this research are intermingled within the jumps in such a way as to prevent the drawing of firm conclusions but, though it did not yield proof, the investigation did provide evidence regarding the causes of twists. These results point to a potential line of research which, if pursued, could provide important information leading to the reduction or eventual elimination of suspension line twists and the dangers associated with them.

AIRCRAFT AND EQUIPMENT FACTORS IN THE OCCURRENCE OF SUSPENSION LINE TWISTS WITH THE T-10 AND MCl-1B PARACHUTES

CONTENTS

	PAGE
INTRODUCTION	1
OBJECTIVE	3
METHOD	3
Research Participants	3
Facilities and Equipment	3
Procedure	4
Self-Report of Suspension Line Twists	4
Visual Count of Suspension Line Twists	5
RESULTS	6
Self-Report Measures, One or More Twists.	6
Effect of Type of Parachute.	7
Effect of Combat Equipment	7
Effect of Aircraft	8
Joint Effects of Aircraft and Combat Equipment	9
Self-Report versus Visual Count Comparisons, One or More Twists.	11
Self-Report Measures, Four or More Twists	13
Effect of Type of Parachute, Four or More Twists	13
Effect of Combat Equipment, Four or More Twists	14
Effect of Aircraft, Four or More Twists.	14

	<u>PAGE</u>
DISCUSSION	14
REFERENCES	18

TABLES

Table 1 - Conditions of deployment for the five jumps of the Basic Airborne Course.	4
Table 2 - Number and percent of jumpers reporting suspension line twists over five training jumps of two classes of the Basic Airborne Course.	7
Table 3 - Number and percent of jumpers from two classes of the Basic Airborne Course reporting suspension line twists during five jumps from C-123 and C-141 aircraft.	9
Table 4 - Number and percent of jumpers from one class (Class 2) of the Basic Airborne Course reporting suspension line twists during one jump without combat equipment (Jump 2) and one jump with combat equipment (Jump 3) from both C-123 and C-141 aircraft.	10
Table 5 - Number and percent of jumpers from two classes of the Basic Airborne Course reporting suspension line twists during one combat equipment jump (Jump 3) from C-123 and C-141 aircraft	11
Table 6 - Number and percent of jumpers with suspension line twists over five training jumps in the Basic Airborne Course broken down by class and method of data collection	12

Table 7 - Number and percent of jumpers from two classes of the Basic Airborne Course over five jumps with C-123 and C-141 aircraft who reported suspension line twists requiring four or more and seven or more revolutions to unwind	15
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AIRCRAFT AND EQUIPMENT FACTORS IN THE OCCURRENCE OF SUSPENSION LINE TWISTS WITH THE T-10 AND MC1-1B PARACHUTES

INTRODUCTION

The MC1-1B, the steerable parachute, offers two important advantages over the older T-10 parachute. With the relatively high maneuverability that is built into the MC1-1B by the removal of portions of several panels of the canopy, it provides an improved ability to steer to particular assembly areas on the drop zone. In addition, it offers a greater latitude in changing direction close to the ground to avoid hazards at the landing site.

There are disadvantages associated with the use of the steerable, however, and the primary one is that entanglements between jumpers in the air are much more dangerous than they were with the more stable, full-canopied T-10. For one thing, because of the modification, the steerable canopy collapses more readily when jumpers collide. Related to that is another serious problem with the steerable which makes it even more dangerous relative to the T-10. That is the danger that is present when one jumper drifts into another in such a manner that the body of the one jumper runs into the canopy of the other, not an uncommon occurrence. The remedy which is taught for that situation is for the first jumper to scramble across the other jumper's canopy until he slips off the side, whereupon his canopy will fill with air, once again, and he will eventually drift free. However, when the parachutes are steerable, the possibility exists that the jumper will fall into the open portion of the other canopy and become entangled within the cone created by the suspension lines of the other parachute. An entanglement of this sort is a very difficult one from which to recover and may lead to the collapse of both parachutes and the deaths of the jumpers involved.

Jumpers may collide and become entangled for various reasons, most of which are specific to the point in time during the jump at which they occur. One reason for collisions soon after the exit of the jumpers from the aircraft is that one or both jumpers may have twists in the suspension lines of their parachutes and may be drifting through the air out of control and unable to avoid other jumpers.

Suspension line twists are the condition wherein the cords suspending the jumper from his canopy have become wrapped around one another into a configuration that resembles a rope. It is cleared by the action of the jumper turning himself in 360° revolutions in the direction opposite to that of the twists. Because of the movement of air through the canopy modifications during the time that the jumper is working to clear the twists, the steerable gradually becomes oriented to the direction of the wind and

drives forward with the wind at a speed that is the sum of the velocity of wind and the natural drive of the parachute (approximately 9.5 miles per hour), a combined speed that can reach as much as 20 to 30 miles per hour or more. When the suspension lines are twisted, the toggle lines by which the parachute is steered are inaccessible to the jumper or unresponsive to his pulls and his parachute drifts out of control until the twists are cleared. It is during this period of fast, free drift that collisions become more likely.

Since jumpers drifting out of control under suspension line twists are a hazard to themselves and to other jumpers, it is important to understand what causes twists in order that steps might be taken to reduce or eliminate them. A number of causes for parachute twists have been proposed and any or all of them may play a role. Among the most frequently mentioned are:

1. Twists are inadvertently packed into the parachutes by the riggers.
2. Twists in the static line in the aircraft produce twists in the suspension lines as the parachute deploys.
3. The pattern of air turbulence behind the aircraft can cause twists.
4. Aircraft speed beyond an optimum can cause twists.
5. Crabbing of the aircraft (flying with the body of the aircraft slightly askew from the line of flight) exposes the jumper coming out of the forward door to a greater than normal air blast and can blow him around and cause twists.
6. The body position the jumper assumes as he exits the aircraft can cause twists.
7. The equipment the jumper wears, because it influences his body position, can cause twists.

Any or all of the above factors may play a role in the occurrence of twists. Discussions with experienced airborne personnel, however, reveal a considerable amount of disagreement concerning the origin of twists. For instance, some claim that combat equipment, weapons case and ruck sack, causes twists because it is bulky and unstable and presents broad, flat surfaces that can act as airfoils and blow the jumper about after his exit from the aircraft. Others, however, say that combat equipment, being the heavy load that it is, exerts a stabilizing influence as the jumper falls through the air and prevents him from being turned by the wind in the manner that would cause twists to develop. Other disagreements among veteran jumpers relate to whether or not each of the hypothetical causes on the above list does, in fact, influence twists and which of the agreed upon influences are the most prominent.

In view of the disparity of opinion which exists about the main causes of suspension line twists and, in consideration of the increased probability of

dangerous entanglements which may result from jumpers with twists, it is of interest to try to determine the relative importance of the factors involved.

The Basic Airborne Course at Fort Benning, Georgia, consisted, at the time of this research, of five parachute jumps under various conditions of deployment such as differences in type of parachute, type of aircraft, and type of equipment carried. By collecting data on the occurrence of twists in jumps under particular sets of conditions, it is possible to gather some evidence regarding the strength of various factors in their occurrence. The individual factors are intermingled within the jumps in such a way as to prevent drawing of firm conclusions about causes, but, if it will not provide proof, this research will develop some evidence about the causes of twists.

OBJECTIVE

The specific objective of this research was to develop evidence of the effects of type of parachute, type of aircraft, and type of equipment carried on the occurrence of suspension line twists during jumps with the T-10 and the MC1-1B parachute.

METHOD

Research Participants

These data were collected on two classes of the Basic Airborne Course at Fort Benning, Georgia, in August of 1979.

Facilities and Equipment

Each class made five parachute jumps over Fryar Field Drop Zone at Fort Benning. With the exception of two jumps for one class which were made exclusively from C-123 Provider aircraft, all jumps were made from both C-123's and C-141 Starlifter aircraft. The C-123 is a reciprocating engine, propeller driven aircraft which, when dropping Basic Airborne Class troops at Fort Benning, Georgia, flies at an airspeed of 115 nautical miles per hour. The C-141 is a jet aircraft and flies at 130 nautical miles per hour when dropping troops from the Basic Airborne Class.

Table 1 sets forth the conditions under which each of the jumps was made for both classes. Two types of parachutes are used during the course. Jumps 1 and 4 made use of the older, full-canopied T-10 parachute modified with an anti-inversion net, and jumps 2, 3, and 5 employed the newer MC1-1B steerable parachute with anti-inversion net.

Table 1

CONDITIONS OF DEPLOYMENT FOR THE FIVE JUMPS OF THE BASIC AIRBORNE COURSE

	Jump				
	1	2	3	4	5
Parachute	T-10	MC1-1B	MC1-1B	T-10	MC1-1B
Equipment	None	None	Combat	None	Combat
Time	Day	Day	Day	Night*	Day
Altitude	1250	2000	1500	1250	1500
Delay between Jumpers	1 sec	2 sec	1 sec	1 sec	1 sec
*Jump #4 was a daylight jump for Class 1					

Jumps were made either with no equipment, except helmet, main parachute, and reserve parachute, or with simulated combat equipment. Combat equipment carried during these jumps in the Basic Course consisted of a long, flat rectangular weapons case (approximately 10" x 33") and an H-Harness and Roll, a long cylindrical kit bag [approximately 10" (diagonal) x 25"] slung beneath the reserve parachute.

All jumps for both classes were done during daylight hours except Jump 4 for Class 1 which was a night jump. Altitudes for the jumps varied from 1250 feet for each of the T-10 jumps to 2000 feet for the first jump with the MC1-1B. The delay between each jumper on each pass over the drop zone was one second, with the exception of the first steerable jump, Jump 2, in which two seconds were allowed between jumpers. The increased delay and altitude for the first steerable jump was to provide an extra margin of safety for the jumpers as they made their initial jumps with the more dangerous steerable parachutes.

Procedure

Self Report of Suspension Line Twists. The prime data of this research were self-reports by the jumpers of the occurrence or non-occurrence of twists in their suspension lines after canopy deployment. On the morning of their first jumps, each class was briefed on what constitutes suspension line twists and were told that they would be asked after each jump if any twists had developed in their lines during that jump. Suspension line twists were

defined for the jumpers as a situation in which the lines are wrapped around one another to such an extent that it required one full-circle revolution to undo them. They were told, specifically, that, if the lines from one riser were merely lying across the lines from the other riser in such a way that they immediately popped free of each other, that condition did not constitute a twist.

The data were taken after the jumpers had landed on the drop zone and had gathered at the assembly area. At that time, each jumper was asked the following question:

"When you checked your canopy on this jump, did you have any twists in your suspension lines?"

If the individual said yes, he was then asked:

"Can you tell me how many?"

If at that point he (or she) didn't seem to be able to provide a specific number, he was prompted by being asked:

"Did you have a few? Quite a few? A lot?"

Because of the difficulty of perceiving the precise number of revolutions that one undergoes in those circumstances, the responses of the jumpers were grouped into the following three categories:

1. 1 to 3 twists (A few).
2. 4 to 6 twists (Quite a few).
3. 7 or more twists (A lot).

Visual Count of Suspension Line Twists

The self-report measures described above, while they were judged to be the best measures available for this study, are subject to question regarding their accuracy. It is conceivable that some individuals could report that they had not had twists when, in fact, they had, because they might feel that their occurrence would reflect discredit upon the jumper for his technique in exiting the aircraft.

Alternately, it is conceivable that some individuals might report having had twists when, in fact, they had not, in order to make their recent experience sound more dangerous and exciting than otherwise. Other individuals might have said yes, they had, or no, they had not, despite the fact that they had been so overwhelmed by the experience of making their first parachute jumps that they were not fully conscious of what was happening to them. To judge from the looks on the faces of some of the jumpers as they go out the door, this last alternative may provide the greatest source of error in these data.

These errors, while they probably do occur, are not likely to cause a serious problem for the interpretation of the data. Each of the errors listed above seems about as likely to cause an underestimate of the true percent age of twists as it is to cause an overestimate. With the large number of jumps that were made during this research, errors in one direction should cancel out errors in the other direction and consequently, they should not obscure any real differences attributable to equipment or aircraft factors.

However, the possibility of errors of this type made it desirable to obtain some independent corroboration of the data taken by self-report. Accordingly, one class of jumpers, Class 2, was observed with binoculars for three jumps from a point halfway down the drop zone and the number of individuals seen to develop twists after canopy deployment were counted.

Data taken in this matter present greater problems than the self-report measures and it was the awareness of these problems that led to the selection of the self-report measures as the data collection method of choice. Because of distance and viewing angle, it is extremely difficult to determine from the ground whether or not an individual has twists in his suspension lines immediately after deployment of his canopy. Consequently, one must watch some jumpers for several seconds to make that determination. Meanwhile, during each second that passes, another jumper comes out of the aircraft and if he has twists they begin to unwind almost immediately. If there is only one or just a few, by the time the jumper is located with the binoculars, the twists could already be out and he would be counted as having had none. To avoid this outcome, the tendency while observing is to decide as quickly as possible whether or not each jumper has twists and to hurry on to the next man out the door. This leads to the opposite error of reporting twists when the initial viewing angle makes the lines appear to be twisted but they actually are not. Both these errors are a danger with this method and for that reason the self-report data was preferred. In spite of these problems, however, in order to provide some check on the veracity of the self-report measures, one class, Class 2, was observed from the drop zone during the first three jumps and frequencies of the occurrence of twists were taken by visual count.

RESULTS

Self-Report Measures, One or More Twists

The data for the first of the analyses to follow are shown in Table 2 which gives both the number and percent of jumpers from both classes in the study who reported suspension line twists during each of the five jumps of the Basic Airborne Course. The data for the comparisons considered below were entered into 2 x 2 contingency tables and analyzed with the Pearson Chi-square Test of Statistical Association (Hays, 1963).

Table 2

NUMBER AND PERCENT OF JUMPERS REPORTING SUSPENSION
LINE TWISTS OVER FIVE TRAINING JUMPS OF TWO CLASSES
OF THE BASIC AIRBORNE COURSE

Jump	Number Jumpers With Twists	Total Jumpers	Percent Jumpers With Twists
1	186	730	25%
2	215	755	28%
3	317	709	45%
4*	217	713	30%
5	286	670	43%
*Night Jump for Class #1, day jump for Class #2			

Effect of Type of Parachute. Although they differ in other ways (e.g., altitude and delay between jumpers), the primary difference between the conditions under which Jump 1 is conducted and the conditions for Jump 2 is that the first jump is made with the T-10 parachute and the second is made with the MC1-1B. Therefore, provided that a large enough sample of jumpers is studied, any differences between Jump 1 and Jump 2 in percent of jumpers with twists can (with appropriate caution) be considered to be evidence of the effects of the parachute in the occurrence of twists. Failure to find differences with this comparison is evidence that neither parachute nor altitude or delay is a cause of twists. Consequently, in order to assess the effects of the type of parachute used, (plus altitude and delay) the numbers of individuals with and without twists on Jump 1 was compared to the numbers of individuals with and without twists on Jump 2. A Chi-square analysis of the proportions of jumpers with twists from Jump 1 (25%) and the proportion from Jump 2 (28%) indicated that there were no statistically significant differences between the two jumps ($\chi^2 = 1.69$, $df = 1$, $p = NS$). The 3% difference in relative number of twists was most likely the result of chance variation.

Effect of Combat Equipment. In order to assess the effect of combat equipment on the occurrence of twists, the proportion of twists that occurred on Jump 2, an MC1-1B jump without equipment, can be compared to the proportion of twists found in Jumps 3 and 5, jumps that were also made with the steerable parachute but for which all jumpers carried combat equipment. The other major

difference between the jumps was that Jump 2 was at 2000 feet with a 2-second delay between jumpers whereas Jumps 3 and 5 were at 1500 feet with a 1-second delay between jumpers. Chi-square analyses of the differences between Jump 2 (28% twists) and each of the combat equipment jumps, Jump 3 (45% twists) and Jump 5 (43% twists), revealed statistically significant differences in each case ($\chi^2 = 41.7$, $df = 1$, $p < .001$, and $\chi^2 = 31.4$, $df = 1$, $p < .001$ respectively). These results indicate that the larger percentages of jumpers with twists for the combat equipment jump were not the result of chance and may be attributable to the effects of combat equipment on the later jumps.

A comparison between the two equipment jumps (Jump 3 with 45% twists and Jump 5 with 43% twists) showed that there was no significant difference between them ($\chi^2 = .574$, $df = 1$, $p = NS$).

A further check on the effects of combat equipment, given that in the preceding section it was shown that type of parachute makes no difference, is to compare the non-combat equipment jump using the T-10, Jump 1 (25% twists), with each of the MC1-1B equipment jumps, Jumps 3 and 5 (45% twists and 43% twists, respectively). These comparisons show that the higher proportions of twists seen for both of the equipment jumps are significant (e.g., reliably) different from the proportion resulting from the non-equipment jump ($\chi^2 = 30.9$, $df = 1$, $p < .001$ and $\chi^2 = 22.4$, $df = 1$, $p < .001$, respectively).

This last analysis also will serve as an additional check on the possibility that the differences in the amount of delay between the jumpers may cause differences in the proportion of twists between the non-equipment, MC1-1B jump, Jump 2, and the equipment jumps with the MC1-1B, Jumps 3 and 5.

Jump 2, being the first steerable jump, is conducted with 2 seconds of delay between each jumper, whereas during Jumps 3 and 5 only 1 second separates one jumper from the next. This difference in delay constitutes a confounding factor for comparisons between the jumps aimed at assessing the effects of combat equipment. If delay between jumpers is relatively short, the jumper has less time to get set in the door. This in turn may cause a less than favorable body position once outside the aircraft and an increased chance of suspension line twists.

This confounding factor cannot be eliminated from the data due to the way the jumps in the airborne course are constituted. However, the comparisons, discussed above, between Jump 1 with the T-10 (which was earlier shown to be equivalent to the MC1-1B in terms of proportion of twists), without combat equipment but with a 1-second delay, and Jumps 3 and 5 with the MC1-1B, combat equipment, and also a 1 second delay, show that, with the amount of delay controlled for, combat equipment still has its large effect on twists.

Effect of Aircraft. Another factor widely considered to be important in the occurrence of twists is the influence of the aircraft. It is impossible to disentangle the separate factors of speed, air turbulence patterns, and different exit procedures in the data reported here, since all three of these variables differ between the C-123 and the C-141 aircraft. It is possible,

however, to examine the different proportion of twists that result when a large number of jumps are made from each aircraft and to attribute the results to differences in the overall set of factors which characterize each aircraft.

The data for that comparison is shown in Table 3 where all the jumps from both classes are grouped according to the aircraft from which they were made. A Chi-square analysis comparing proportions of jumpers with and without twists coming out of the C-123 (32% with twists) with the proportion coming out of the C-141 (38% with twists) showed that the C-141 produced significantly more twists than the C-123 ($\chi^2 = 13.18$, $df = 1$, $p < .001$).

Table 3

NUMBER AND PERCENT OF JUMPERS FROM TWO CLASSES OF THE
BASIC AIRBORNE COURSE REPORTING SUSPENSION LINE TWISTS
DURING FIVE JUMPS FROM C-123 AND C-141 AIRCRAFT

Aircraft	Number Jumpers With Twists	Total Jumpers	Percent Jumpers With Twists
C-123	754	2352	32%
C-141	467	1225	38%

Joint Effects of Aircraft and Combat Equipment. Given that type of aircraft was shown to be important in the occurrence of twists, with the C-141 having been found to be more likely to produce them, and, also, that the relative percent of jumps from each aircraft varied from jump to jump, it is important to determine if the significant difference in proportion of jumpers with twists found between Jump 2 and Jump 3 was most probably attributable to combat equipment or was possibly the result of there having been a larger percentage of C-141 jumps made on Jump 3 than on Jump 2.

Due to problems with the aircraft, the C-141 was grounded during Jumps 1 and 2 for Class 1 and all jumps for that class on that day were made from C-123 aircraft. This raises the possibility that it was the influence of the increase in C-141 jumps rather than the presence of combat equipment that caused the increase in twists from Jump 2 to Jump 3. To examine that possibility, the data from Class 2, the only class which made any jumps from the C-141 during Jump 2, was broken down by jump and by aircraft. That data is presented in Table 4.

The table shows that the percentages for each aircraft on a given jump are similar for both Jump 2 (C-123, 27% twists; C-141, 21% twists) and Jump 3 (C-123, 41% twists; C-141, 44% twists). They are very different between

Table 4

NUMBER AND PERCENT OF JUMPERS FROM ONE CLASS (CLASS 2) OF THE
BASIC AIRBORNE COURSE REPORTING SUSPENSION LINE TWISTS
DURING ONE JUMP WITHOUT COMBAT EQUIPMENT (JUMP 2) AND
ONE JUMP WITH COMBAT EQUIPMENT (JUMP 3) FROM
BOTH C-123 AND C-141 AIRCRAFT

Jump 2

Aircraft	Number Jumpers With Twists	Total Jumpers	Percent Jumpers With Twists
C-123	54	199	27%
C-141	36	170	21%

Jump 3

Aircraft	Number Jumpers With Twists	Total Jumpers	Percent Jumpers With Twists
C-123	72	177	41%
C-141	71	161	44%

jumps, however, with the C-123 showing a rise of 14% twists from the non-equipment jump to the combat equipment jump and the C-141 showing an increase of 23%. These changes in the proportion of twists for each aircraft were analyzed by Chi-square to determine if combat equipment makes a significant difference in jumps from each aircraft. Those analyses showed that, when jumps were conducted from either the C-123 or the C-141, the presence of combat equipment produces a large and reliable increase in the number of twists reported ($\chi^2 = 7.71$, $df = 1$, $p < .01$ and $\chi^2 = 19.9$, $df = 1$, $p < .001$, respectively).

There is, however, still a difference within a given combat equipment jump between the proportions of twists in jumpers coming out of each aircraft. Table 5 breaks down the data from both classes of jumpers for Jump 3, with combat equipment, into the proportions of twists from each type of aircraft. There, it can be seen, that jumps from the C-123 result in 40% jumpers with twists and jumps from the C-141 result in 49% twists. This difference also is statistically significant ($\chi^2 = 6.22$, $df = 1$, $p < .025$).

Table 5

NUMBER AND PERCENT OF JUMPERS FROM TWO CLASSES OF THE
BASIC AIRBORNE COURSE REPORTING SUSPENSION LINE TWISTS
DURING ONE COMBAT EQUIPMENT JUMP (JUMP 3)
FROM C-123 AND C-141 AIRCRAFT

Aircraft	Number Jumpers With Twists	Total Jumpers	Percent Jumpers With Twists
C-123	144	359	40%
C-141	173	350	49%

Self-Report versus Visual Count Comparisons, One or More Twists

Table 6 presents the data from both methods of data collection, self-report and visual count, used in this experiment. The data is further broken down by class, since, only for Class 2, were both methods used.

Chi-square analyses of the data from both methods of the proportion of jumpers with twists during Jump 1 showed that the 25% twists reported by the jumpers themselves was not significantly different from the 28% twists obtained by visual count ($\chi^2 = 1.13$, $df = 1$, $p = NS$). The different, usually lower, total number of jumpers in the self-report data reflects the fact that, due to work details formed immediately upon the arrival of the jumpers at the

Table 6

NUMBER AND PERCENT OF JUMPERS WITH SUSPENSION LINE TWISTS
OVER FIVE TRAINING JUMPS IN THE BASIC AIRBORNE COURSE
BROKEN DOWN BY CLASS AND METHOD OF DATA COLLECTION

Method	Self Report			Self Report			Visual Count		
	1			2			2		
Jump	Number Jumpers With Twists	Total Jumpers	Percent Jumpers With Twists	Number Jumpers With Twists	Total Jumpers	Percent Jumpers With Twists	Number Jumpers With Twists	Total Jumpers	Percent Jumpers With Twists
1	96	370	27%	90	360	25%	104	365	29%
2	125	386	32%	90	369	24%	143	368	39%
3	174	371	47%	143	338	42%	162	360	45%
4*	119	348	34%	98	365	27%			
5	154	347	44%	132	323	41%			

*Night jump for Class #1, day jump for Class #2

assembly area, not all individuals could be located after a jump to report on the occurrence of twists.

A Chi-square analysis of the differences between data collection methods on Jump 3 (Self-report, 42% twists; Visual count, 45% twists) was also not significant ($\chi^2 = .51$, $df = 1$, $p = NS$).

These analyses, then, indicated that, for Jumps 1 and 3, both methods of data collection produced the same results. As can be seen from Table 6, however, there was a considerable disparity between the proportion of twists obtained in Jump 2 by the self-report method (24%) and the proportion obtained by the visual count method (39%). This difference between methods was significant ($\chi^2 = 17.8$, $df = 1$, $p < .001$).

There is no certain explanation for this discrepancy. It is possible that due to the potential bias in the visual count measure, the observer overestimated the number of jumpers with twists that he thought he saw. It is also possible that for some reason, such as uncertainty about the possible use of such information by the cadre to grade jumper performance, some of the jumpers of Class 2 were reluctant to admit having had twists and failed to report them, thus lowering the percentage for the class on that jump. Conceivably, both sources of error could have been contributed to the outcome. It is interesting, while considering that possibility, to note that the percent of twists reported for Class 1 was 32%, which falls halfway between the percentages from each data collection method for Class 2.

Self-Report Measures, Four or More Twists

The analyses to this point have included data for jumpers who may have had as few twists in their lines as one and as many as seven or more. A jumper drifts out of control for a relatively brief time while unwinding only one twist and is undergoing a correspondingly smaller risk of collision and entanglement than one who is trying to unwind multiple twists. To investigate the influence of parachute and equipment factors on the occurrence of the more dangerous multiple twists, the self-report data shown in Table 7 on the estimated number of twists in the lines of jumpers who had them, were analyzed by Chi-square in the same manner as for the preceding analyses.

Effects of Type of Parachute, Four or More Twists. To inquire into the influence of the type of parachute in the more dangerous multiple twists, as was done in previous analyses, the percentage of jumpers with four or more twists for Jump 1 (T-10 and no equipment) was compared to the same percentage from Jump 2 (MC1-1B and no equipment). A Chi-square analysis on those proportions (Jump 1, 04% twists, Jump 2, 05% twists) showed that the differences were not significant ($\chi^2 = 1.35$, $df = 1$, $p = NS$).

The same comparison for seven or more twists (Jump 1, 01%; Jump 2, 01%) produced the same result of no significant differences ($\chi^2 = .30$, $df = 1$, $p = NS$). Thus, for neither classification of multiple twists was there any effect to be attributed to type of parachute.

Effect of Combat Equipment, Four or More Twists. To assess the effect of combat equipment on the occurrence of the more serious multiple twists, Jump 2 (MC1-1B, no equipment) was compared to Jump 3 (MC1-1B, combat equipment). The proportion of jumpers reporting four or more twists from Jump 2 (05%) was found to be significantly lower than that of Jump 3 (12%) by the Chi-square test ($\chi^2 = 24.35$, $df = 1$, $p < .001$). Similarly, the proportion of jumpers reporting seven or more twists from Jump 2 (01%) was compared to that from Jump 3 (04%) and that comparison showed that jumps without combat equipment caused significantly fewer twists of that severity than jumps with combat equipment ($\chi^2 = 10.96$, $df = 1$, $p < .001$).

A similar set of comparisons was made between Jump 2, MC1-1B without equipment, and Jump 5, the second MC1-1B jump, with combat equipment. The first of these comparisons showed that, for four or more twists, Jump 2 (05% twists), without equipment, was significantly lower in twists than Jump 5 (10% twists), with combat equipment ($\chi^2 = 14.5$, $df = 1$, $p < .001$). A comparable result was obtained for jumpers reporting seven or more twists with Jump 2 (01% twists) showing significantly fewer in that category than Jump 5 (03% twists) as determined by Chi-square ($\chi^2 = 6.8$, $df = 1$, $p < .01$).

Effects of the Aircraft, Four or More Twists. Presented at the bottom of Table 7 are the data from each aircraft, C-123 and C-141, from all five jumps by both classes of the Basic Airborne Course, of the number of jumpers reporting multiple twists requiring four or more and seven or more twists to unwind. To see if there were differences between the aircraft in the occurrence of the more serious multiple twists, the data from each aircraft for each category of twists were compared by Chi-square.

For the data from the four-or-more-twists category, the analysis showed that the C-123 with 06% twists was significantly lower in twists than the C-141 with 08% ($\chi^2 = 4.050$, $df = 1$, $p < .05$). The comparison between the aircraft on the data from the seven-or-more-twists category, however, showed that there was no difference between the C-123, with 02% twists, and the C-141, also with 02% twists ($\chi^2 = 2.028$, $df = 1$, $p = NS$).

DISCUSSION

Because of the lack of experimental control over the variables under study and the resulting uncertainty about the validity of the inferences that can be drawn from the data, this research is best described as a quasi-experiment (Campbell and Stanley, 1963). Although the results of the comparisons reported here are partially confounded by scheduled variation in such measurably different conditions as parachute employed, altitude of jump, delay between jumpers, differing exit procedures, etc., they do present evidence of a strong effect of combat equipment and a somewhat less strong effect of type of aircraft as factors in the occurrence of suspension line twists.

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Table 7

NUMBER AND PERCENT OF JUMPERS FROM TWO CLASSES OF THE
BASIC AIRBORNE COURSE OVER FIVE JUMPS WITH C-123 AND C-141 AIRCRAFT
WHO REPORTED SUSPENSION LINE TWISTS REQUIRING FOUR OR MORE AND
SEVEN OR MORE REVOLUTIONS TO UNWIND

Jump	Four or More			Seven or More		
	Number Jumpers With Twists	Total Jumpers	Percent Jumpers With Twists	Number Jumpers With Twists	Total Jumpers	Percent Jumpers With Twists
1	26	730	04%	10	730	01%
2	36	755	05%	8	755	01%
3	84	709	12%	26	709	04%
4*	22	713	03%	3	713	00%
5	67	670	10%	20	670	03%
<u>Aircraft</u>						
C-123	141	2211	06%	44	2308	02%
C-141	95	1130	08%	23	1202	02%

*Night jump for Class #1, day jump for Class #2

combat equipment jumps produced large and significant increases in twists relative to all non-equipment jumps to which they were compared and this difference held up even when comparisons were limited to an individual class of jumpers and to particular aircraft employed. Furthermore, combat equipment also produced reliable increases in both categories of the more dangerous multiple twists - four or more and seven or more twists.

The aircraft factor also showed up in most of the comparisons made, and, though the differences between jumps from different aircraft were smaller than those between jumps with and without combat equipment, they, too, were statistically significant. The single exception involved the comparison between aircraft of the data from the seven-or-more category of multiple twists. Apparently, since each type of aircraft (or, rather, the constellation of characteristics associated with each aircraft -- airspeed, air turbulence patterns, exit procedures, etc.) produced the same percentage of twists from the seven-or-more category, the aircraft influences the occurrence of twists only up to about four to six revolutions.

There was no effect attributable to type of parachute in the self-report data. Approximately the same percentage of jumpers reported twists with the T-10, without combat equipment, for Jump 1 as they did with the MC1-1B, without equipment, for Jump 2. However, the disparity between the self-report data and the visual count data for Class 2, Jump 2, signals the need for caution in drawing conclusions on that issue. If the self-report data from Jump 2 is an underestimate of the actual percentage of twists that occurred, a parachute factor could have been washed out of the data as a result.

The same caution might apply to the combat equipment comparison between Jump 2 and Jumps 3 and 5. However, the large increase in twists between Jump 1, with the T-10 and no equipment, and Jumps 3 and 5, with the MC1-1B plus equipment, makes it very unlikely that the combat equipment effect is not real. In addition, it eliminates the possibility that amount of delay between jumpers is the explanation for the differences between the jumps without equipment and the jumps with it -- an alternative explanation for the differences between Jump 2 and Jumps 3 and 5.

These data only provide information regarding the effects of parachute, combat equipment, and aircraft. Other of the factors that are listed in the Introduction and some that aren't, probably influence twists, as well, but it was not possible to study them in this research. Further work would be needed to assign relative importance to each of the factors likely to be involved.

It should be pointed out that, during the course of these observations, there were no entanglements between jumpers. This illustrates that, under training conditions at Fort Benning, regardless of the incidence of twists, actual entanglements are rare events. They do occur, however, and, when they do, they are dangerous and are usually fatal to several jumpers throughout the Army every year.

Except for the inexperience of the Basic Course jumpers, these data were taken under ideal conditions -- jumpers rigidly following regulation exit

procedures, aircraft flying at regulation altitudes and airspeeds, appropriately safe intervals and patterns of stagger between jumpers from each door, and standardized, relatively light loads of combat equipment. The high percentage of twists occurring here during the combat equipment jumps may be close to the minimum that can be expected. Jumps under combat conditions with jumpers pouring out of both doors in back-to-belly "daisy chains", at lower altitudes to reduce exposure to enemy fire, carrying bulkier and heavier loads of equipment, should produce a much larger percentage of twisted jumpers, as well as less room in the air between them to work the twists out and less time to get it done before setting up for a landing.

The Army is currently engaged in a reexamination of airborne doctrine and is considering the possibility of incorporating "extremely low altitude" combat jumps (from as low as 500 feet, Hirst, 1980b) into airborne operations. Considering that the one principal advantage of the steerable parachute is that it allows the jumper to steer around obstacles on the drop zone (Hirst, 1980a), the reliable occurrence of a high proportion of jumpers drifting out of control on combat equipment jumps is a cause for concern. While the Army weighs the advantages and disadvantages of low altitude jumps and prepares to employ them, if that is the decision, further research to understand the primary causes of twists and how to eliminate them could provide timely input to the process.

If combat equipment does eventually prove to be the main cause of twists, the complete redesign of that equipment may be warranted. The goal of that effort would be to make the jumper and his equipment a more aerodynamically stable unit while still enabling him to unlimber his weapon and equipment quickly and efficiently as soon as he hits the ground.

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